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Forecasting Art Coverage in South Africa Using the Multilayer Perceptron Neural Network

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***Abstract* - In this research article, the ANN approach was applied to analyze ART coverage in South Africa. The employed annual data covers the period 2000-2018 and the out-of-sample period ranges over the period 2019-2023. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting ART coverage in South Africa. The results of the study indicate that the country is likely to record an ART coverage of around 65% over the period 2019-2023.Therefore the government is encouraged to intensify demand creation for HIV testing and ART services and improve ART access for both documented and undocumented migrant workers, and strengthen the system of tracking loss to follow up ART clients.**

Keywords: ANN, ART coverage, Forecasting.

I. INTRODUCTION

South Africa is one of the countries in the world with high HIV prevalence rates and was noted to be struggling to meet its 90-90-90 targets (UNAIDS, 2019). The country has approximately 7.7 million people living with HIV (UNAIDS, 2019). The national ART program aims to offer ART services for free to all the people living with HIV. ART services are offered at all the levels of the health delivery system. There is evident integration of HIV and TB programs. All HIV positive patients are screened for TB and those who do not have the disease are commenced on TB preventive therapy if there are no contraindications to isoniazid. On the other hand all TB patients are tested for HIV. The aim of TB/HIV collaboration is to significantly reduce morbidity and mortality due to TB/HIV (PERFAR COP 20 South Africa). The National ART program faces a myriad challenges which delay the achievement of the 90-90-90 targets (PERPFAR COP19). Firstly there are many loss to follow up individuals before ART initiation. In 2019 ,the country operational plan (COP) reported that in 2018 only 80% of people who tested HIV positive were commenced on antiretroviral therapy (ART). Poor HIV treatment outcomes are associated with gaps in service delivery and poor quality of services in public health facilities. In addition, poor adherence due to various reasons, antiretroviral drug resistance and drug resistant TB complicates the management of ART patients.

Scaling up of ART services in the country is key in order to control the HIV epidemic. The government's commitment and private sector involvement helps in early detection and treatment of both TB and HIV. Forecasting models play a vital role in revealing the future trends of the epidemic and are useful tools in the assessment of the impact of corrective measures implemented by the state. Several models have been applied in public health and these include ARIMA, exponential smoothing and machine learning methods. The ARIMA model was proposed by Box and Jenkins in the 1970s and have been widely used because of their simplicity. The ARIMA model is specified as ARIMA (p,d,q).,where p and q are the autoregressive (AR) and moving average (MA) parts and d represents the nonseasonal differences(Nyoni &Nyoni 2019 a &b).In this paper we apply the artificial neural network ANN (9,12,1) to forecast ART coverage in South Africa. The artificial neural network model consists of 3 layers: input, hidden and output layers connected by weights (Fajnica et al, 2016; Zhang, 2003; Kaushik &Sahi, 2018; Yan et al, 2019)

II. LITERATURE REVIEW

Barnabas et al (2020) did a household randomized ,unblended trial of delivery of ART in the community compared with the clinic in rural and peri-urban settings in Kwazulu Natal ,South Africa and Sheema district ,Uganda .After community based HIV testing ,people living with HIV were randomly assigned (1:1:1) with mobile phone software to community based ART initiation with quarterly monitoring and ART refills ,ART initiation at the clinic followed by mobile van monitoring and refills (hybrid approach) or standard clinic ART initiation and refills. The primary outcome was HIV viral suppression at 12 months. The study concluded that in high and medium HIV prevalence settings in South Africa and Uganda, community based delivery of ART

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significantly increased viral suppression compared with clinic based ART particularly among men. In another study, Johnson et al (2017) assessed South Africa's progress towards the 2020 targets and variations in performance by province .A mathematical model was fitted to the HIV data for each of South Africa's provinces and for the country as a whole .The study results revealed that ART coverage varied between 43% in Gauteng and 63 % in Northern Cape and most provinces face challenges in reaching the remaining two 90% targets. A mathematical modelling approach was also applied by Hontelez et al (2013).In the study nine mathematical models were developed for South Africa's HIV epidemic elimination. All models confirmed previous predictions that the HIV epidemic in South Africa can be eliminated through universal testing and immediate treatment at 90 % coverage. Adam &Johnson (2009) estimated adult antiretroviral treatment coverage in South Africa using the Markov model .The findings of the study showed that ART coverage in 2008 varied between Provinces from 25.8% in the Free State to 71.7%.

III. METHOD

The Artificial Neural Network (ANN) is actually a data processing system consisting of a large number of simple and highly interconnected processing elements resembling a biological neural system. It has the great capability of learning from an experimental or real data set to describe the nonlinear and interaction effects with great accuracy. ANN-based curve fitting technique is one of the most extensively applied artificial intelligence methods that are employed for forecasting and prediction purposes. It consists of just 3 layers i.e., input layer, hidden layer, and output layer, the present work includes the number of years as input layer and the annual TB incidence in South Africa as output data for the network. In this research work, our ANN is based on the hyperbolic tangent function.

Data Issues

This study is based on annual ART coverages (referred to as A series in this study) in all age groups in South Africa. The data covers the period 2000-2018 while the out-of-sample forecast covers the period 2019-2023. All the data employed in this research paper was gathered from the World Bank online database.

IV. FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
23.368	16.000	0.00000	62.000
Std. Dev.	C.V.	Skewness	Ex. kurtosis
22.401	0.95860	0.39659	-1.3986
5% Perc.	95% Perc.	IQ range	Missing obs.
undefined	62.000	45.000	0

ANN MODEL SUMMARY FOR ART COVERAGE IN SOUTH AFRICA

Table 2: ANN model summary

Variable	A
Observations	10(After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	9
Hidden Layer Neurons	12
Output Layer Neurons	1
Activation Function	Hyperbolic Tangent Function
Back Propagation Learning:	
Learning Rate	0.005
Momentum	0.05
Criteria:	
Error	
MSE	

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MAE	

Residual Analysis for the ANN model

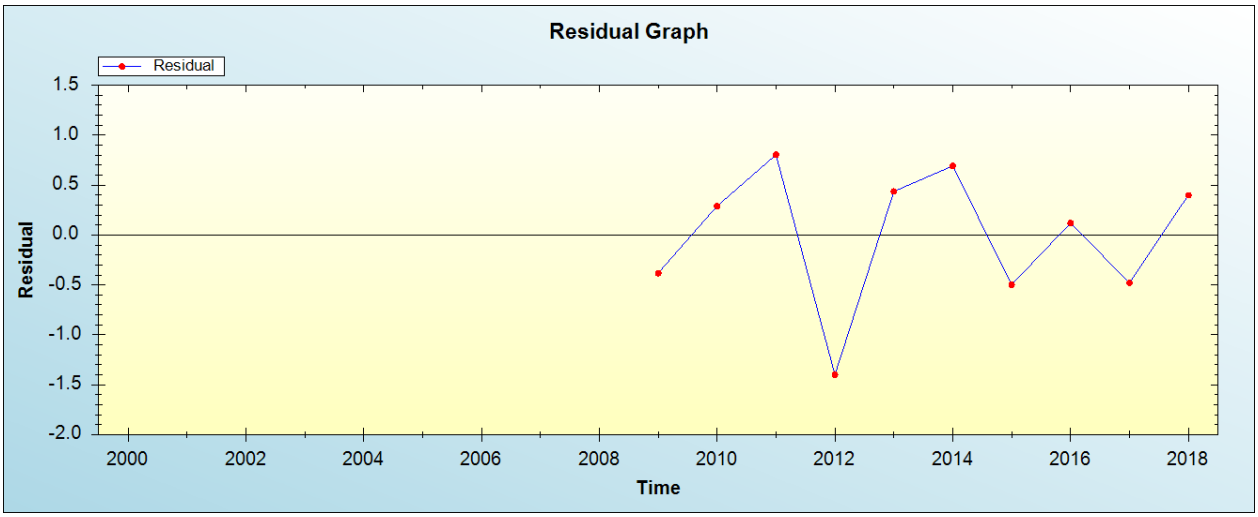

Figure 1: Residual analysis

In-sample Forecast for A

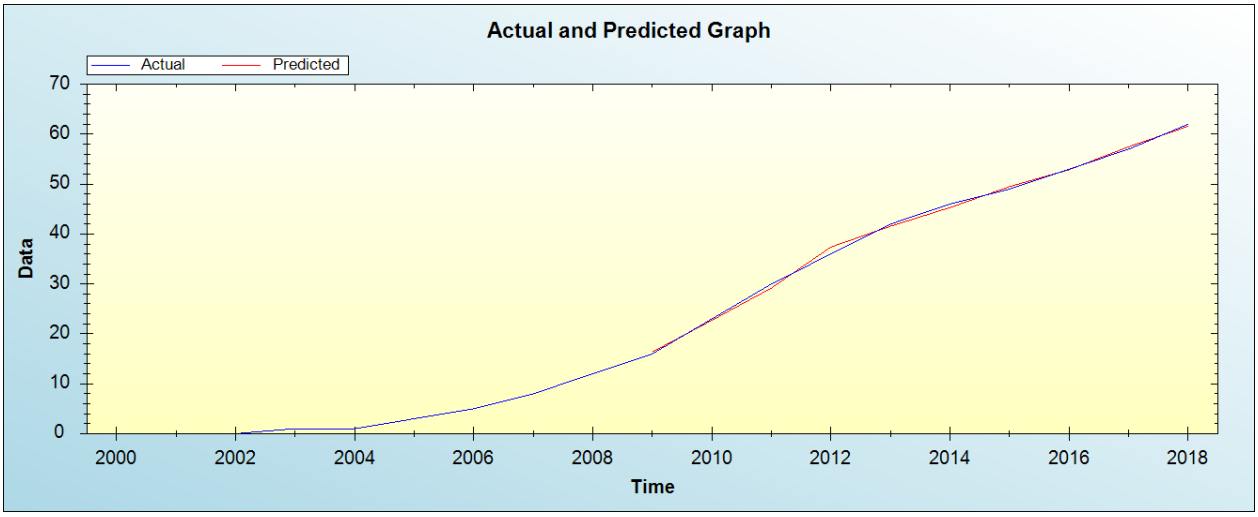

Figure 2: In-sample forecast for the A series

Figure 2 shows the in-sample forecast for A series.

Out-of-Sample Forecast for A: Actual and Forecasted Graph

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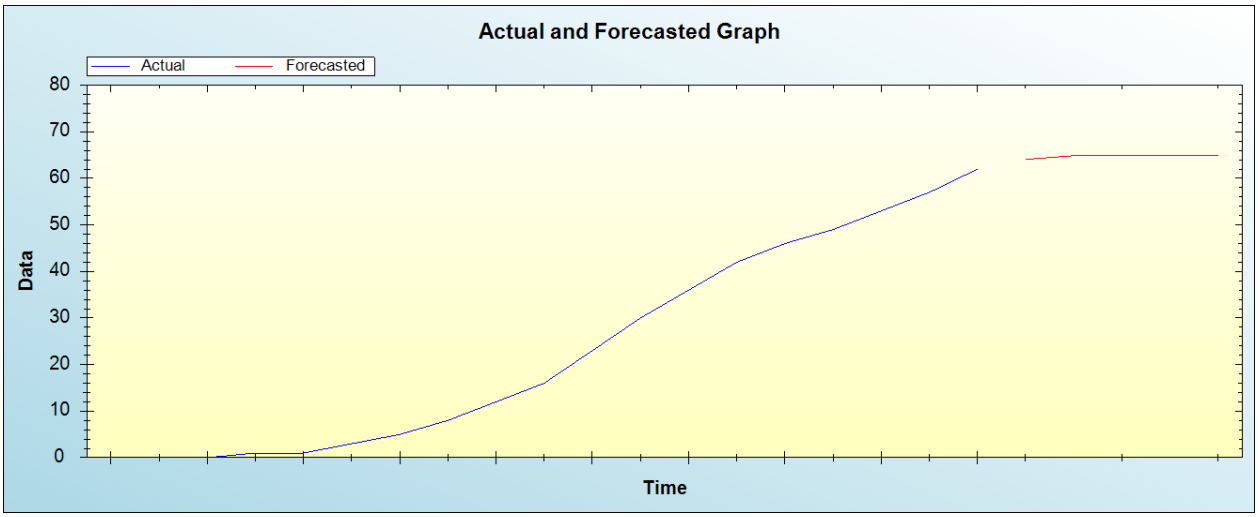

Figure 3: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasted ART coverage
2019	64.0891
2020	64.8692
2021	65.0020
2022	65.0270
2023	64.8709

Over the study period the minimum and maximum ART coverage was 0 and 62% respectively with an average of 23.4%. The data used in this study is positively skewed with excess kurtosis of -1.3986. This means that the data is not normally distributed. The residual graph and model evaluation criteria (Error, MSE, and MAE) indicate that the applied model is stable and suitable in forecasting ART coverage in South Africa. The neural network model simulates the observed data well as shown in Figure 2. The model projects that ART coverage will be around 65 % over the period 2019-2023.

V. CONCLUSION & RECOMMENDATIONS

South Africa recorded an improvement in the provision of ART services in the country because it recorded an upward trend in ART coverage over the period 2000-2018.This shows that the country is committed to making sure that people living with HIV have access to antiretroviral therapy. However, the country is still facing a lot of challenges in the provision of ART services which include loss to follow ups, defaulters and ART drug resistance. The model predicted that the ART coverage will likely be around 65% in the out of sample period. The government is encouraged to intensify demand creation for HIV testing services and ART services, improve ART access for migrant workers who are either documented or undocumented and strengthen the tracking of loss to follow up clients.

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